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Meta-analysis of feeding trials to estimate energy requirements of dairy cows under tropical condition

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ABSTRACT

A meta-analysis of feeding trials was performed to determine the metabolizable energy requirement for maintenance (ME_m) and efficiency of utilization of the metabolizable energy intake (MEI) for milk production (k_L) of *Bos taurus* and *Bos taurus* × *Bos indicus* crossbreds dairy cows in the tropics. The database contained 231 treatment means ($n = 148$ *Bos taurus* and $n = 83$ *Bos taurus* × *Bos indicus*) from 60 feeding trial studies. A linear regression of MEI with milk energy output adjusted to a zero energy balance ($E_{L(0)}$, MJ/kg $BW^{0.75}$/day) was fitted using a mixed model with the study as the random effect and the genotype (G) as dummy variable (*Bos taurus* = 0 and *Bos taurus* × *Bos indicus* = 1). The ME_m was calculated as the intercept and k_L as the reciprocal of the slope of the regression. The dairy cow genotype affected the ME_m requirements ($P = 0.05$) and tended to affect k_L ($P = 0.08$). The equation fitted was MEI (MJ/kg $BW^{0.75}$/day) = 0.754 (±0.076) − 0.196 (±0.102) × G + [1.522 (±0.126) + 0.368 (±0.210) × G] × $E_{L(0)}$. Thus, *Bos taurus* × *Bos indicus* crossbred dairy cows have ME_m requirement that was 26% lower (0.558 ± 0.103 *vs.* 0.754 ± 0.076 MJ/kg $BW^{0.75}$/day) but k_L tended to be 19% lower (0.53 ± 0.10 *vs.* 0.66 ± 0.05) than *Bos taurus* cows. These results support the hypothesis that *Bos taurus* × *Bos indicus* crossbred dairy cows have a lower ME_m, but lower net energetic efficiency for milk production than *Bos taurus* dairy cows. This study may contribute to adjustments in feeding system energy recommendations for dairy cows under tropical condition.

1. Introduction

In the current energy systems for dairy cattle, the net energy or metabolizable energy (ME) requirements for maintenance (ME_m) and efficiency of utilization of the ME intake for milk production (k_L) were derived from indirect calorimetric trials mainly using Holstein or Holstein-Friesian cows (Blaxter, 1962; NRC, 2001; CSIRO, 2007; INRA, 2007; NorFor, 2011). However, *Bos taurus* × *Bos indicus* crossbreeds are the main genotypes that are used in tropical dairy farms, due to heterosis and complementarity between highly productive and adapted tropical breeds (Madalena et al., 1990).

Abbreviations: BCS, body condition score; BW, body weight; DE, digestible energy; DEI, DE intake; E_B, body energy change; E_L, milk energy output; $E_{L(0)}$, milk energy output adjusted for zero energy balance; k_L, efficiency of utilization of the metabolizable energy intake for milk production; ME, metabolizable energy; MEI, ME energy intake; ME_m, ME requirement for maintenance; TDN, total digestible nutrients; TRE, total reserve energy.

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Furthermore, there is substantial evidence that *Bos indicus* beef cattle have lower ME_m than *Bos taurus*, due to lower viscera size and activity, lower rate of body protein turnover, lower internal fat and/or lower body heat loss under tropical climate (Koong et al., 1985; Solis et al., 1988; Marcondes et al., 2013). In contrast, the milk response to concentrate supplementation in *Bos indicus* (Teixeira et al., 2011) seems lower than that of *Bos taurus* dairy cows (Bargo et al., 2003). Thus, I hypothesized that *Bos taurus* × *Bos indicus* crossbreds dairy cows have lower ME_m requirements but lower net energetic efficiency for milk production than *Bos taurus* dairy cows under tropical environments. However, there is not enough empirical evidence to support this hypothesis due to the insufficient number of energy metabolism trials with dairy cows in the tropics.

Due to the greater cost of measurements, only recently have begun studies to investigate the energy metabolism of dairy cattle using respirometric chamber in Brazil (Silva, 2011). Feeding trials analyses could be an alternative approach to accurately determine the energetic requirements (Van der Honing et al., 1977; Agnew et al., 2003; Mandok et al., 2013). In this approach, ME intake (MEI) and milk energy output can be accurately measured, while retained or mobilized body energy (BW) can be indirectly measured by BW change and body condition score (BCS) (Waltner et al., 1994; Fox et al., 1999; Yan et al., 2009). Therefore, due the considerable number of feeding trials on dairy cows in Brazil in the past 30 years (Souza et al., 2014), I hypothesized that meta-analysis of feeding trials can be alternative approach to develop a Brazilian energy system requirement for dairy cows. The objective of this study was to perform a meta-analysis of feeding trials to determine the ME_m and k_L of *Bos taurus* and *Bos taurus* × *Bos indicus* crossbreds dairy cows.

2. Materials and methods

2.1. Dataset

A dataset was built from observations that were reported in 60 studies ($n = 231$ treatment means; 752 cows) that were published in Brazilians journals (R. Bras. Zootec., Sci. Rural, Pesq. Agropec. Bras., and Rev. Bras. Saúde Prod. An.) from 1996 to 2013 or reported in graduate student theses, using the keywords “dairy cows” and “energy”. Other journals were searched (Arq. Bras. Med. Vet. Zootec., Acta Scientarum Anim. Sci., Revista Caatinga, Revista Ceres, and Sci. Agri), but were not founded studies that meet the criterias. The criterias that were adopted for data inclusion in the dataset were (1) experiments conducted under tropical conditions; (2) cows under different feeding management systems and production levels; (3) estimation of fecal output using total collection, external or internal markers; and (4) adequate description of cows (*e.g.*, breed, BW, milk yield and milk composition) and experimental diets (*e.g.*, ingredient and chemical composition). In studies without BCS (1–5 scale) information, a fixed value of 2.50 was adopted because is it closets to typical BCS of dairy cows in middle stage of lactation (Roche et al., 2009).

The dataset was composed (number/total) for multiparous (0.76), primiparous (0.14) and of both (0.10). The dataset was classified by genotype: *Bos taurus* (37 studies; $n = 148$ treatments means; Table 1) and *Bos taurus* × *Bos indicus* crossbred (23 studies; $n = 83$ treatments means; Table 2). The complete dataset is available in an Excel® file on-line Supplementary Material.

Table 1
Summary statistics of the database from feeding trials of *Bos taurus* dairy cows under tropical conditions ($n = 148$; 37 studies).[a]

Item	Mean	Median	Minimum	Maximum	SD
Forage diet, g/kg dry matter (DM)	584.6	600.0	400.0	900.0	107.0
Crude protein diet, g/kg DM	149.4	151.5	93.4	195.6	18.4
Neutral detergent fiber diet, g/kg DM	399.0	394.7	262.4	664.3	73.8
Ether extract diet, g/kg DM	28.4	26.0	10.6	73.8	11.5
Total digestible nutrients diet, g/kg DM	655.5	656.2	532.1	779.9	49.1
Digestible energy (DE) diet, MJ/kg DM	12.07	12.10	9.82	14.39	0.91
Metabolizable energy (ME) diet, MJ/kg DM	10.44	10.47	8.30	12.63	0.86
DM intake, kg/day	18.2	18.3	12.1	24.3	2.3
Neutral detergent fiber intake, g/kg BW/d	12.6	12.8	8.0	17.4	2.3
Total digestible nutrient intake, kg/day	11.9	11.8	7.9	17.1	1.7
DE intake, MJ/day	219.1	218.1	145.9	316.0	30.7
ME intake, MJ/day	189.4	187.8	125.4	275.1	27.2
Milk yield, kg/day	22.2	21.8	11.6	34.4	5.0
Milk fat, g/kg	36.4	36.1	28.8	46.3	3.7
Milk protein, g/kg	32.6	32.1	25.2	39.3	2.5
Milk lactose, g/kg	44.3	44.9	40.0	49.7	2.1
Milk energy, MJ/kg	2.93	2.91	2.25	3.41	0.18
Body weight (BW), kg	570	568	450	671	44.9
Body condition score (1–5)	2.7	2.6	2.5	3.2	0.2
Days in milk	137	130	63	225	38
BW change, kg/day	0.30	0.31	−0.87	1.37	0.37

[a] Table S1 of the supplementary material. Reference (Appendix).